Developmental Milestones of Linear Growth in Humans: Children Undergo Six Major Postnatal Growth Spurts from Infancy to Maturity

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Growth is not Continuous

Often, our vision of the growth of children is that it is continuous, especially if we just look at annual growth measurement, or growth charts developed by health agencies, such as the Center for Disease Control.   However, several scientists have shown that "growth is not a continuum" and there are growth spurts which occur in both animals and humans.

Growth Spurts in Children are Real

As any parent could tell you, "Children Do Grow in Spurts," and adolescence is not the first time that they grow by "leaps and bounds." In addition to the pubertal growth spurt, children experience at least five other major spurts, in the period from infancy to maturity.

Major Growth Spurts were Documented

Contrary to past assumptions of only two major postnatal growth spurts (neonatal, and pubertal), longitudinal height growth studies of children have shown the appearance of multiple spurts.

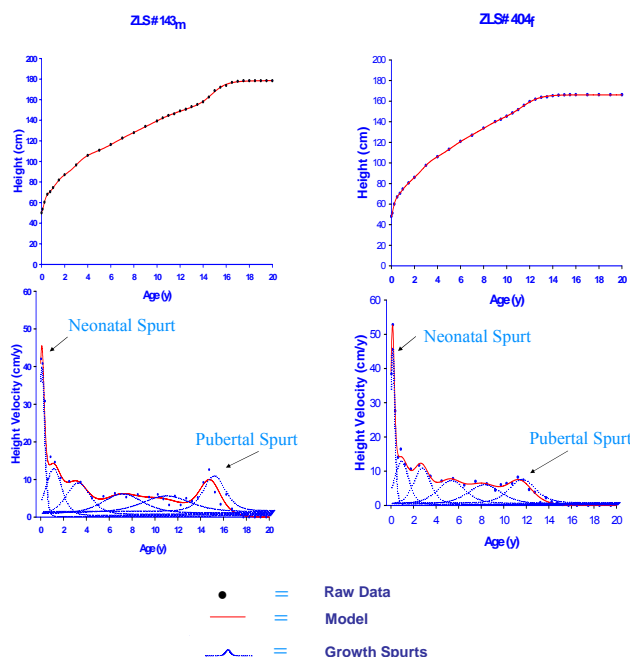## A Model to Characterize Human Growth Patterns

Although growth is not continuous, children's growth curves can be described quite well using a mathematical function that is continuous. For example, if one assumes that height growth is due to the combination of six logistic-growth processes, then the following mathematical model is appropriate for describing these curves from infancy to maturity (1,2):

$$H(t) = H_o + \sum_{i=1}^{6} \frac{H_i}{1 + \exp(-k_i(t - t_i))} + \varepsilon(t)$$

Where,
$H(t)$, is the total height at age, t, years after birth;
H_o, is related to the height at birth;
H_i, is the asymptotic height reached by process i;
k_i, is the growth rate of process i
t_i, is the age when process i reaches its peaked height velocity (phv); and
$\varepsilon(t)$ is the residual term at age ,t, accounting for measurement errors, growth fluctuations due to seasonal effects and model bias .

Fit of the Hexaphasic-Logistic Growth Model to Serial Height Data

Figure 1. Height and height velocity curves of a male (ZLS#143m) and female (ZLS# 404f) child showing a neonatal and pubertal growth spurt, in addition to four other spurts.

Milestones of Linear Growth

Growth Process	Ages @ phv for Child ZLS# 143m Years	Ages @ phv for Child ZLS#404f Years
Neonatal	0.09	0 .12
Infantile	1.05	0.86
Early- Childhood	3.13	2.65
Middle-Childhood	6.94	5.16
Late-Childhood	10.69	8.13
Pubertal	14.80	11.40

Environmental Significance

■ The model presented here can serve as an essential tool for identifying and characterizing height growth patterns in humans.

■ Growth spurts are important developmental milestones that mark key points that may influence the toxicological effects of environmental agents in both children and adults.

Cancer Incidence Rates

■ Growth spurts during adolescence are associated with peaks in the incidence of teenage bone cancers (i.e.,osteosarcoma, Ewing sarcoma).

■   Children with certain non-cancerous bone diseases have an increased risk of later developing osteosarcomas as an adult (i.e., Paget disease).

■ The risks of breast cancers in females exposed to ionizing radiation is highest during the pubertal "growth spurt."

■ Growth spurts in children are associated with peaks in the incidence of soft tissue cancers (i.e., rhabdomyosarcomas.) .

Alkaline Metal Uptake in Bones

■ The rate of uptake of alkaline metals in children's bones (i.e. calcium, lead, strontium, radium) is highest during periods of rapid growth.

■ Up to the age of 20 y, two primary maxima of radium-224, radium-226 and strontium-90 concentrations were observed in children, which corresponded directly with the neonatal and pubertal growth spurts.

Impact on Risk Assessment

There are specific periods or windows of susceptibility during development, when toxicants might permanently alter the morphology and/ or function of biological systems in children. The results of this research will help risk assessors identify those periods that are associated with rapid growth rates in children.

References

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